

STABILITY OF WHEAT GENOTYPES ADAPTED IN TROPICAL MEDIUM AND LOWLAND

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ABSTRACT

The research objective was to select wheat genotypes that can adapt on the medium and low plains. Twenty-seven genotypes and three varieties of wheat were grown in four locations in the medium and low plains since June-October 2009. The experiments were arranged using a randomized complete block design repeated three times. Analysis of variance performed at each location followed by a test of homogeneity of error range, the combined analysis of variance and yields stability analysis. Genotype x environment interaction significantly affecting yield. Stable genotypes and widely adaptable across locations were G-1 (1.94 t.ha⁻¹), G-20 (1.24 t.ha⁻¹), H-14 (1.85 t.ha⁻¹), H-19 (1.59 t.ha⁻¹), H-20 (1.69 t.ha⁻¹), H-21 (1.48 t.ha⁻¹), 162 (1.62 t.ha⁻¹), 80 (1.63 t.ha⁻¹), 82 (1.78 t.ha⁻¹), 91 (1.49 t.ha⁻¹), and 142 (1.45 t.ha⁻¹). Genotypes adapted in productive environment were G-18 (1.23 t.ha⁻¹), G-19 (1.63 t.ha⁻¹), 185 (1.30 t.ha⁻¹), 40 (1.33 t.ha⁻¹) and 42 (1.52 t.ha⁻¹). Genotypes adapted in marginal environments were 28 (2.22 t.ha⁻¹), H-1 (1.61 t.ha⁻¹), H-8 (1.65 t.ha⁻¹) and H-16 (1.68 t.ha⁻¹). Genotype was selected as an improvement material in the wheat breeding in medium and lowland of tropical regions.

Keywords: wheat selection, tropical, yield stability and adaptability

INTRODUCTION

Wheat is one of the important food crops in Indonesia. Increasing demands of wheat as raw material are used for noodles, cakes, bread and other food industries, so that wheat is almost a staple food after rice in Indonesia. FAO data

(2007) showed that consumption of wheat in Indonesia in 1990 only 9.14 kg/capita/year, and in 2005 increased to 20 kg/capita/year. The availability of wheat in Indonesia is still met from imports, so it is vulnerable to the fluctuation of raw material shortages and price that can threaten the stability of the national economy. Therefore, the fulfillment of domestic wheat can be done with the planting of wheat in Indonesia.

The spread of wheat in the world located in areas with an average temperature of 15-25°C. Wheat can grow and produce well at temperatures 20-25°C and optimal growth is achieved at a temperature of 4-31 °C. Wheat cultivation in the tropics is strongly influenced by physical factors, especially climate because of incompatibility may cause failure of the harvest season (Azwar *et al.*, 1988). Climatic factors that determine the growth and production including rainfall, temperature and humidity (Azwar, 1987; Bahar *et al.* 1988 and Ismal, 1984). High rainfall resulted in higher intensity of disease caused by the fungi *Fusarium* and *Helminthosporium*, attacking each panicle and leaves (Azwar *et al.*, 1988). High temperatures reduce harvest day plant and yield components such as the amount of leaves, plant height, productive tiller and number of flowers (Rawson, 1987).

Constraints faced in wheat cultivation in Indonesia is still limited to wheat growing environments on high plains with a relatively low temperature and low humidity. While the potential area of wheat cultivation in the medium and lowland plains. Wheat varieties released in Indonesia i.e. cv. Timor, Nias, Selayar, and Dewata are encouraged to be planted in the highlands, with the yield average 2.98 t.ha⁻¹. Several studies demonstrate the potential yield of wheat in the highlands of Malino (1350 m asl)

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can achieve 3-5 t.ha⁻¹ (Hamdani *et al.*, 2002), in the Urut Sewu, Boyolali (675 m asl) ranged between 0.71-2.34 t.ha⁻¹ (Dahlan *et al.*, 2003), and in Tosari (1850 m) potential yield reached 6.5 t.ha⁻¹ (Pabendon *et al.*, 2010). Saunders (1988), argued that with irrigation, fertilization and maintenance of appropriate wheat yields could reach 5 t.ha⁻¹ and will decrease on a lower altitude. Aggarwal and Penning de Vries (1989) demonstrated the potential of wheat with good irrigation ranged from 3-5 t.ha⁻¹, and yields will higher at altitudes between 500–2000 m asl.

Varieties of wheat for the tropics should have a resistance to environmental variability, particularly heat stress, drought and marginal land, in addition to resistance to major pests and diseases as well as seed germination before harvest (Villareal *et al.*, 1984). Wheat genetic manipulation is an appropriate way in order to obtain potential genotypes that adapt in plain medium and lowland tropical areas. Evaluation of the introduction and selection of wheat lines from segregating populations have been conducted (Kusmana and Subandi, 1985; Dasmal *et al.*, 1992; Supriyanta *et al.*, 2007).

Wheat crops grown at several locations with different altitudes showed different yield results (Bahar *et al.*, 1988). Genotype x environment interaction is limiting factor that can cause the expression of plant is not optimal so making it difficult for breeders to select high yielding genotypes. Genotype and environment interactions is a form of process plants adapt to the environment so that these plants can survive and breed in different environmental conditions (Nor and Cady, 1979). This is because the environment always affects the genetic potential of plants to express and plants will hold a different response to the complexity of different environmental (Gardner *et al.*, 1985), and this phenomenon causes plants infrequent express the maximum potential yield (Kramer, 1980). Nor and Cady (1979) argue that the seeds yield are very important criteria in evaluating the adaptability and yield stability of a genotype. Measurement of the relative stability of the appearance of a genotype or population of plants in a broad range of areas is crucial to determine the efficiency of plant breeding program (Liang *et al.*, 1966).

Planting wheat in several locations, including medium and lowland plains is one way to obtain an adaptive genetic material in

accordance with the desired target environment. Development of wheat cultivar can be customized for a variety of different environments or in specific environment is the ultimate goal for breeding programs. Adaptation to varying environments can be known from the level of interaction with different environments. Genotypes considered to be more adaptive or stable if it has an average high yield but have low fluctuations if planted in a very diverse environments. According to Becker and Leon (1988) success in develop a new variety must show superior yield and other important agronomic characters. They need a reliable advantage on a variety of environmental conditions. Plant breeders generally agree on the importance of yield stability.

Selection of wheat genotypes based on response to environmental changes expected will determine the potential for widespread genetic yield results will be passed to offspring. If a potentially unstable genotype which means adapting to a specific area or to adapt the environment so these genotypes have adapted these genes. According to Allard and Bradshaw (1964), stability is needed in dealing with unpredictable environments. Allard (1999) put forward a character would be if there is a gene expression control and to be in the right environment, and some characters will not express themselves even in the right environment if the genes controlling these characters do not exist.

Tan *et al.* (1979) suggested the relative difference in the appearance of a genotype from one environment to another environment which is always followed by a fixed pattern and can be measured through regression. Confirmed Eagle *et al.* (1977), regression coefficients can be used by plant breeders to gauge stability of a character in a genotype or population. Analysis of the stability model of Eberhart and Russell (1966) is widely used to help plant breeders overcome the difficulties that arise from the existence of genotype x environment interactions to measure the yield stability with the criteria, if the environmental index regression coefficient (b_i) has a value equal to one ($b = 1$) and deviation from the deviation of the regression is zero ($Sd_i^2 = 0$) then the characters are measured on a stable. If these criteria are not met then the character is not stable. According Finlay and Wilkinson (1963) using regression coefficients for determining adaptability of genotypes with condition the value of deviation of

regression is zero than if the value of regression coefficient (b) equal to one then has the appearance of a stable genotype in the whole environment that has a wide adaptability. If $b > 1$ indicates stability below average, genotypes having the appearance of which is sensitive to environmental changes and can only adapt in a productive environment. If the value $b < 1$ then the stability of the genotypes have above average but were not sensitive to environmental changes, and these genotypes adapted to the environment that is not productive. Based on the analysis of stability and this adaptation is expected to be selected wheat genotype genotype-environment adaptable to medium and low tropical plains.

MATERIALS AND METHODS

Research were conducted at four locations that include lowland (300 m asl) namely Ngajum (Malang) and Muneng (Probolinggo), and medium plain (600 m asl) namely Tumpang (Malang), and Dau (Batu). The experiment was conducted from June to October 2009. Thirty genotypes of wheat were used, which consists of 27 lines and three varieties as checks, which are Dewata, Nias, and Selayar, Urea 100 kg.ha⁻¹, SP36-100 kg.ha⁻¹, and KCI 100 kg.ha⁻¹. The instrument used is a set of wheat cultivation tools, measuring tools, labels, and stationery.

Experiments at each location were based on the experimental method using a randomized block design (RBD). Thirty genotypes of wheat were used as treatment was repeated three times. Each genotype was planted in plots of size bed 1.2mx 5m. Each plot consisted of 12 rows. Analysis of variance performed at each location to investigate the diversity of genotypes at each location (Table 1).

Prior to conducting combined analysis, the error variance at each location tested based on Bartlett (LeClerg, 1962; Petersen, 1994):

$$M = \gamma \left[a(\ln \bar{s}_i^2) - \sum_i \ln s_i^2 \right],$$

$$\bar{s}_i^2 = \frac{\sum_i s_i^2}{a}, \text{ and } C = 1 + \frac{a+1}{3a\gamma}.$$

In formula, γ = degree of freedom residual in each location, s_i^2 = means square residual at it location, a = location numbers. If ratio value M/C is smaller than the value table of Chi-square

$\chi^2_{(0.05;\gamma)}$, then the error variances are not heterogeneous, so it can be combined variance analysis based on Singh and Chaudhary (1979) and McIntosh (1983) to assess the effect of genotype x environment interaction (Table 2).

The difference of genotype means yield were tested with the method of Scott-Knott grouping analysis (Gasperz, 1992). Stability of the yields were analyzed using a linear model of Eberhart and Russell (1966):

$$Y_{ij} = \mu_i + \beta_i I_j + \delta_{ij},$$

where Y_{ij} = means of i -th genotypes in j -th locations, μ = means of all genotypes in all locations, β_i = regression coefficient of the i -th genotypes on environmental index indicating genotypes response to environmental variation,

$$I_j = \left(\frac{\sum_i Y_{ij}}{v} \right) - \left(\frac{\sum_i \sum_j Y_{ij}}{vn} \right) = \text{environmental}$$

index, i.e. the average deviation from the genotype in an environment of all average, δ_{ij} = deviation of means square of i -th genotype in the j -th environment, v = number of genotypes, n = number of environments.

A genotype is stable if it has the appearance

of the regression coefficient $b = \frac{\sum_j Y_{ij} I_j}{\sum_j I_j^2}$ were

not significantly different from the one and the

deviation $\left(\bar{S}d^2 = \frac{\sum_j \hat{\delta}_{ij}^2}{n-2} - \frac{S_e^2}{r} \right)$ were not

significantly different from the zero.

Table 1. Analysis of variance for randomized block design in a location

Source	df	Means Square	Fstat
Block	$r - 1$	MS1	
Genotypes	$g - 1$	MS2	MS2/MS3
Residual	$(r-1)(g-1)$	MS3	
Total	$rg - 1$		

Remarks: r = replication, g = genotypes

Table 2. Combined analysis of variance for randomized block design across location

Source	Degree of Freedom (df)	Means Square (MS)	Fstat
Locations	l-1	MS1	MS1/MS2
Replication (Locations)	L(r-1)	MS2	
Genotypes	g-1	MS3	MS3/MS4
Genotypes x Locations	(g-1) (l-1)	MS4	MS4/MS5
Residual	l(r-1) (g-1)	MS5	
Total	Rlg-1		

Adaptation of genotypes determined by Finlay and Wilkinson (1963). If deviation of a genotype is zero and has a value of $b > 1$, then the genotype is responsive to the productive environment so that these genotypes adapted to a productive environment. If a genotype has a value of $b < 1$, then the genotype is less responsive to environmental changes so that these genotypes adapted to the environment less productive. Analysis of variance using the software DAASTAT (Onofri, 2006), different test of Scott-Knott clustered using SASM-Agri (Althaus *et al.*, 2001), and the adaptation and yield stability analysis using CropStat 2.7 for Windows (Crop Research Informatics Laboratory, 2007).

RESULT AND DISCUSSION

Analysis of variance at each location showed the differences in genotypes performance grown in the all locations (Table 3). It was showed

that yield differences by environmental difference. Differences in respon-se shown by the difference of the grain at each site and there were differences in genetic potential possessed by the genotype of wheat.

Bartlett test of homogeneity showed the error variance in the four locations are not heterogeneous (Table 4) so combined analysis of variance conducting to predict the effect of genotype x environment interaction.

Combined analysis of variance showed that there was genotype x environment interaction effect on the performance of wheat (Table 5). This means that wheat genotypes requires a suitable environment so that there is an appearance of wheat genotypes is not consistent in different environments and rank performance genotypes tested were changed at each location. In addition, location and genotype also contributed to the differences in yields.

Table 3. Means square wheat yields (t per ha) in each location

Source	df	Muneng	Ngajum	Tumpang	Dau
Block	2	0.14	0.88	0.88	0.37
Genotypes	29	0.36*	0.43*	0.24*	0.19*
Residual	58	0.13	0.06	0.04	0.10
Total	89	0.21	0.20	0.13	0.13
CV (%)		25.03	16.62	13.81	16.29

Remarks: *significant at F5% test

Table 4. Analysis of error variance homogeneity according to bartlett's test

Locations	s ²	ln(s ²)
Muneng	0.13	-2.04
Ngajum	0.06	-2.81
Tumpang	0.04	-3.22
Dau	0.1	-2.30
Sum	0.33	-10.38
M	22.93	
C	1.01	
M/C	22.76ns	
$\chi^2_{(0.05;58)}$	76.78	

Remarks: s² = residual variance, ns = non significant

Table 5. Means square combined analysis of variance wheat yield (t per ha)

Source	df	MS
Locations	3	3.71*
Replication (Locations)	8	0.57
Genotypes	29	0.52*
Genotypes x Locations	87	0.24*
Residual	232	0.08
Total	359	0.20
CV (%)		18.2

Remarks: df = degree of freedom, MS = means squares, CV = coefficient of variation

Wheat yields of each genotype at each location reflect changes in rankings as a result of environmental influences. In the lowland Muneng, appearance genotype yield are divided into two groups. Nias and the Dewata have the same appearance yields, and higher than Selayar (Table 6). There are 18 genotypes of wheat that have a similar appearance with the yields of the Dewata and Nias. In the lowland Ngajum, genotypes tested are divided into three groups. Nias and Selayar have the same yields and lower than the Dewata. In Ngajum there are four genotypes that have higher yields compared with the three

checks. In Tumpang, appearance genotypes tested spread into four groups. Nias and Selayar have the grain yield lower than the Dewata. In Tumpang there are three genotypes that have higher performance compared with the yields of the highest checks. In Dau showed that Nias and Dewata have yield that are not significantly different and both showed a higher yield compared to Selayar. Based on the trial, there are two different genotypic groups based on the trait of yield, and 15 genotypes have the appearance of which is not significantly different from Nias and Dewata.

Based on the results of trial at each different location shows that there are changes in the number of genotypes in each group at each location. This indicates there is a change in the performance ranking genotypes and the check varieties. The difference in yield between genotypes at the same location is caused by differences in genetic potential that is owned by genotypes. Changes in genotype rank at different locations due to differences in genotype response differently to the environment to avoid environmental stress. Genotypes are able to exploit environment resources optimally will have the performance of high yield.

Analysis of stability and adaptability of wheat genotypes is needed to determine the consistency of performance ratings and yield of wheat in a large environment. The results show that there are 12 genotypes tested that have a stable performance in all locations (Table 6). Stable genotypes have a regression coefficient equal to one and deviation is zero. This shows the genotypes yields linear to environmental productivity. Stable genotypes can be used as materials to develop superior cultivars of wheat in tropical areas, medium and low altitude. Selected genotype is G-1 (1.94 t.ha⁻¹), G-20 (1.24 t.ha⁻¹), H-14 (1.85 t.ha⁻¹), H-19 (1.59 t.ha⁻¹), H-20 (1.69 t.ha⁻¹), H-21 (1.48 t.ha⁻¹), 162 (1.62 t.ha⁻¹), 80 (1.63 t.ha⁻¹), 82 (1.78 t.ha⁻¹), 1991 (1.49 t.ha⁻¹), and 142 (1.45 t.ha⁻¹).

Table 6. Yields of wheat genotypes across locations

No.	Genotypes	Yield (t.ha ⁻¹)				Means	Stability parameters	
		Lowland		Medium land			b	\overline{Sd}^2
		Muneng	Ngajum	Tumpang	Dau			
1	G-1	1.95 a	2.13 a	1.58 b	2.10 a	1.94	0.46±0.82	0.05
2	G-3	0.98 b	2.00 a	1.50 c	1.66 b	1.54	0.67±1.41	0.21*
3	G-16	1.93 a	1.14 c	1.86 a	1.75 b	1.67	0.14±1.26	0.16*
4	G-17	1.45 a	2.35 a	1.28 c	1.80 b	1.72	0.35±1.63	0.29*
5	G-18	0.93 b	0.98 c	1.18 d	1.84 b	1.23	2.04±0.25*	-0.03
6	G-19	1.52 a	1.62 b	1.64 b	1.75 b	1.63	0.43±0.13*	-0.03
7	G-20	0.96 b	0.85 c	1.28 c	1.87 a	1.24	2.09±0.57	0.01
8	G-21	1.45 a	1.58 b	1.03 d	2.19 a	1.56	1.96±0.94	0.08*
9	H-1	1.47 a	1.57 b	1.59 b	1.80 b	1.61	0.67±0.11*	-0.03
10	H-8	1.69 a	1.60 b	1.66 b	1.66 b	1.65	0.00±0.13*	-0.03
11	H-9	1.72 a	1.41 c	1.10 d	1.61 b	1.46	0.29±0.92	0.07*
12	H-14	1.96 a	1.82 b	1.68 b	1.95 a	1.85	0.22±0.42	-0.01
13	H-16	1.59 a	1.58 b	1.68 b	1.85 a	1.68	0.59±0.13*	-0.03
14	H-19	1.66 a	1.80 b	1.36 c	1.53 b	1.59	-0.24±0.63	0.02
15	H-20	1.64 a	1.53 b	1.74 b	1.84 b	1.69	0.50±0.30	-0.02
16	H-21	1.26 b	1.64 b	1.38 c	1.64 b	1.48	0.60±0.50	0.00
17	28	2.05 a	2.22 a	2.20 a	2.18 a	2.16	0.12±0.26*	-0.03
18	162	1.53 a	1.23 c	1.72 b	2.00 a	1.62	1.25±0.72	0.03
19	185	0.94 b	1.30 c	0.94 d	1.94 a	1.28	2.19±0.55*	0.00
20	38	1.42 a	1.57 b	1.84 b	2.08 a	1.73	1.28±0.49	0.00
21	40	1.03 b	0.91 c	1.32 c	2.07 a	1.33	2.44±0.56*	0.01
22	42	1.10 b	1.14 c	1.54 c	2.30 a	1.52	2.63±0.53*	0.00
23	80	1.47 a	1.67 b	1.34 c	2.05 a	1.63	1.35±0.51	0.00
24	82	1.56 a	1.77 b	1.54 c	2.23 a	1.78	1.50±0.36	-0.02
25	85	1.10 b	1.05 c	2.05 a	2.16 a	1.59	2.06±1.48	0.24*
26	91	1.60 a	1.10 c	1.56 b	1.69 b	1.49	0.57±0.82	0.05
27	142	0.94 b	1.40 c	1.44 c	2.04 a	1.45	2.07±0.55	0.00
28	Nias	2.01 a	1.42 c	1.35 c	2.13 a	1.73	1.07±1.17	0.14*
29	Dewata	1.38 a	1.67 b	1.80 b	1.97 a	1.70	0.99±0.51	0.00
30	Selayar	1.08 b	1.26 c	1.50 c	1.11 b	1.24	-0.28±0.64	0.02
Average		1.45	1.51	1.52	1.89	1.59		
Environment index		0.30	-0.15	-0.08	-0.07			

Remarks: Numbers followed by same letter in a column are not significantly different in Scott-Knott grouping method 5%

Analysis of stability and adaptability of wheat genotypes is needed to determine the consistency of performance ratings and yield of wheat in a large environment. The results show that there are 12 genotypes tested that have a stable performance in all locations (Table 6). Stable genotypes have a regression coefficient equal to one and deviation is zero. This shows the genotypes yields linear to environmental productivity. Stable genotypes can be used as materials to develop superior cultivars of wheat in tropical areas, medium and low altitude. Selected genotype is G-1 (1.94 t.ha⁻¹), G-

20 (1.24 t. ha⁻¹), H-14 (1.85 t. ha⁻¹), H-19 (1.59 t per ha), H-20 (1.69 t per ha), H-21 (1.48 t per ha), 162 (1.62 t per ha), 80 (1.63 t per ha), 82 (1.78 t per ha), 1991 (1.49 t per ha), and 142 (1.45 t per ha).

Five genotypes had developed suitable in productive environments, namely the G-18 (1.23 t.ha⁻¹), G-19 (1.63 t.ha⁻¹), 185 (t.ha⁻¹), 40 (1.33 t.ha⁻¹) and 42 (1.52 t.ha⁻¹). These genotypes have a regression coefficient value above one and the deviation value equal to zero. Genotypes that have a regression coefficient value above one indicate responsive to environmental changes (Finlay and

Wilkinson, 1963). Usually these genotypes respond strongly to environmental changes in the extreme. If the genotype is given a highly productive environment then these genotypes will have high yield, and if the environment becomes marginal then these genotypes will have a very low yield. To obtain a high yield the genotypes should be developed at a specific location or at the optimum environment conditioned and released as a superior site specific local varieties.

In this research also acquired a potential wheat developed in marginal environments, i.e. 28 (2.22 t.ha⁻¹), H-1 (1.61 t.ha⁻¹), H-8 (1.65 t.ha⁻¹) and H-16 (1.68 t.ha⁻¹). Suitable wheat developed in marginal environments characterized by the regression coefficient values below one and the deviation is zero. Coefficient values below one indicate the genotype is less responsive to environmental changes (Finlay and Wilkinson, 1963). Genotypes are not responsive to environmental conditions that productive. Although genotyping is conditioned on a highly productive environment, but it will not increase yield. Genotypes was developed to appropriate specific marginal environments, or is conditioned on marginal environments, such as minimum tillage farming, intercropping or low input. The genotypes that have a deviation value is not equal to zero is a genotype that is difficult to predict the yield outcome in a broad range of environments Eberhart and Russell (1966).

Environmental productivity is one important factor that determines the performance of the crop. Basic causes of differences between genotypes in yield stability is the occurrence of genotype x environment interaction, i.e. the genotype ranking depending on certain environmental conditions in which it growth up. In this study, Muneng have high productivity because it has a positive environmental index value is high (Table 6), and other locations including the category of low productivity due to its lower environmental index values and negative.

CONCLUSIONS

Appearance of wheat yield in tropical lowland and medium land is influenced by genotype x environment interactions. Wheat genotypes that have a stable yield outcome and selected in all locations is the G-1 (1.94 t.ha⁻¹), G-20 (1.24 t.ha⁻¹), H-14 (1.85 t.ha⁻¹), H-19 (1.59 t.ha⁻¹), H-20 (1.69

t.ha⁻¹), H-21 (1.48 t.ha⁻¹), 162 (1.62 t.ha⁻¹), 80 (1.63 t.ha⁻¹), 82 (1.78 t.ha⁻¹), 1991 (1.49 t.ha⁻¹), and 142 (1.45 t.ha⁻¹). Genotypes of wheat potentially developed in productive environment was G-18 (1.23 t.ha⁻¹), G-19 (1.63 t.ha⁻¹), 185 (1.30 t.ha⁻¹), 40 (1.33 t.ha⁻¹) and 42 (1.52 t.ha⁻¹). Genotypes potentially developed in marginal environments is 28 (2.22 t.ha⁻¹), H-1 (1.61 t.ha⁻¹), H-8 (1.65 t.ha⁻¹) and H-16 (1.68 t.ha⁻¹).

Selected wheat genotypes with wide adaptation or specific adaptation to environments can be used as materials for genetic recombination of wheat adapt the medium and low altitude tropical regions.

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